OMD-551 - Basics of Bio Medical Instrumentation

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UNIT-I

TITLE:

Origin of Bio-Potential and its Propagation

OBJECTIVE:

The Students are able understand the Bio Potentials of human body

APPLICATIONS:

1. ECG
2. EMG
3. ERG

UNIVERSITY QUESTIONS:

1. Define Action & Resting potential
2. Define All or nothing Law
3. Write Short notes on: origin of Bio potential

NOTES

Origin of Bio potentials and its Propagation

The fluid which lies outside the cell membranes is called extra-cellular fluid.

The fluid which lies inside the cell membranes is called the Intra cellular fluid.

Chemical composition of Extra cellular and Intra cellular fluids

	Extra cellular fluid	Intra cellular fluid
Na^+	142 milli mol / Lit	10 Milli Mol/lit
K^+	4 Milli Mol / Lit	140 Milli Mol / Lit
Ca^{++}	1.2 Mill Mol / Lit	0.00005 Milli Mol / Lit
Mg^{++}	0.6 milli Mol / Lit	29 Milli Mol / Lit
CL^-	103 Milli Mol / Lit	4 Milli Mol / Lit
HCO_3^-	28 milli mol / Lit	10 milli mol / Lit
Phosphates	1.3 milli mol / Lit	25 milli mol / Lit
SO_4^-	0.5 milli mol / Lit	1 milli mol / Lit
Glucose.	90 mg / dl	0 - 20 mg / dl
Amino Acids	30 mg / dl	200 mg / dl
Cholestrol.	0.5 g / dl	2 to 95 mg / dl

Protein
Lipids
Carbohydrate
Cytoplasm
Ribosome
Lysosome
Mitochondria

* The Extra cellular fluid contains large quantity Sodium and small quantity of Pottasium.
* But Intra cellular fluid, the concentration of Pottassium ions is more than the concentration of Sodium ions.
* Similarly concentration of Phosphates and proteins are more in the extra cellular fluid.
* concentration of chlorides is more in the extra-cellular fluid.
* The correct concentrations of ions are necessary for the normal function of the cells & Body
* The cell membrane consist of a lipid bilayer with large numbers of Protein molecules.
* It constitudes a barrier for the movement of water soluble substances between the extra cellular and Intra cellular fluid regions
* The transport of the substances through the cell membrane occurs by diffusion (which is also called as passive transport) and active transport.
* Diffusion takes place either Through fine molecular spaces in the membrane (or) in combination with a carrier protein
* When cell membrane moves molecules or ions uphill against a concentration gradient the process is called Active transport
* Particularly sodium ions, Pottassium ions, Calcium ions, Chloride ions and most of the amino acids are actively transported through cell membranes.
* Active transport is divided into two types according to the source of the energy used to cause the transport

Active Transport

- Primary active transport
- Secondary active transport

* Primary Active transport:

The energy is derived directly from the adenosin triphosphate (ATP) (or) some other high energy phosphate compound.

* Secondary Active transport:

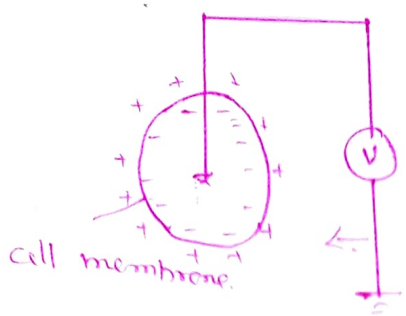
The Energy is derived secondarily from ionic concentration gradients that have been created in the first place by primary active transport.

* Both transports depend upon carrier protein that penetrate through the membrane.

* Examples for Primary Active transport
  * Sodium - potassium pump
  * Calcium pump

Resting potential and Action potential

* The concentration of potassium and chloride ions is more inside than the outside & the charge balance is not achieved
* An equilibrium is reached with potential difference across the membrane.
* Such that negative ions are on the inside and positive on the outside.
* (The Membrane potential caused by the different concentration of ions is called the Resting Potential of the cell.)



Polarised cell with Resting potential $-70mV$

Characteristics of Resting potential:

1. The value of resting potential is maintained as a constant.
2. It is strongly depending on temperature
3. Permeabilities of different cell types vary, the corresponding resting potential vary as well. It varies from -60 to $-100mV$
4. By Goldman's Equations, the Resting Potential of a cell can be written as

$$V_r = -\frac{KT}{q} \ln \left[\frac{P_K [K^+]_i + P_{Na} [Na^+]_i + P_{Cl} [Cl^-]_o}{P_K [K^+]_o + P_{Na} [Na^+]_o + P_{Cl} [Cl^-]_i} \right]$$

where K = Boltzmann's constant $= 1.38 \times 10^{-23}$ J/K.

T = Absolute temperature of the cell in Kelvin

q = Charge of Electron. $= 1.602 \times 10^{-19}$ C.

P_K = Permeability of Potassium ion.

P_{Na} = Permeability of Sodium ion.

P_{Cl} = Permeability of chlorine ion.

$[K^+]$, $[Na^+]$ & $[Cl^-]$ = Concentration of potassium, sodium and chlorine ion

Subscripts i and o Indicate inside the cell and outside the cell.

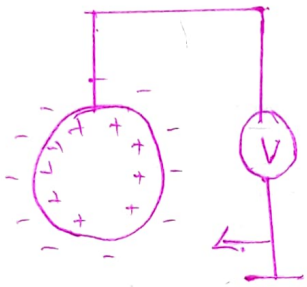
5. If $P_{Na}=0$ & $P_{Cl}=0$ then Goldman equations is reduced in to Nernst equations

$$V_r = -\frac{KT}{q} \ln \left[\frac{[K^+]_i}{[K^+]_o} \right] = -94.9 mV$$

Action Potential

* It is a spike of electrical discharge that travels along the membrane of a cell.

* When the permeability of membrane changes, Sodium ions are not allowed to either inside the cell. It constitutes an ionic current which reduces the barrier. The net result is avalanche effect

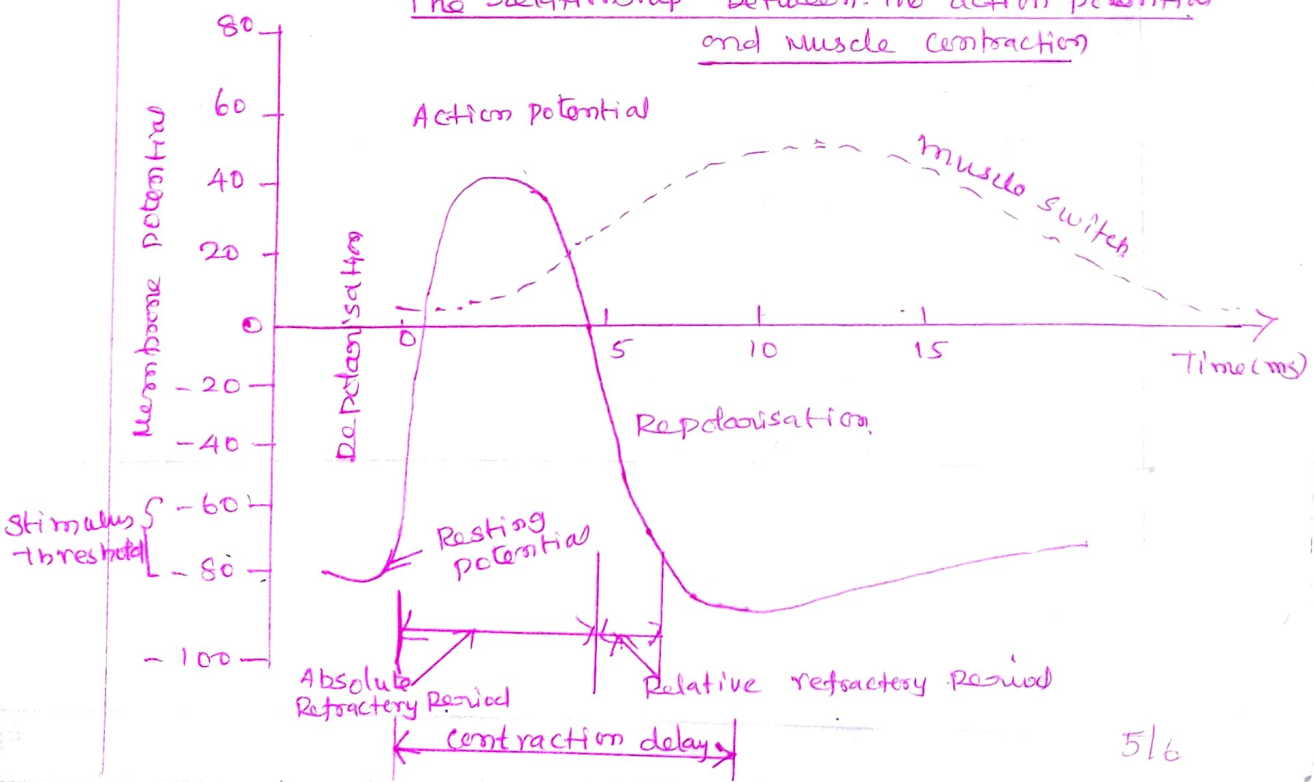


Depolarised cell during an action potential + 20 mv.

* The cell has positive potential on the inside due to imbalance of Potassium ions. The positive potential of cell membrane during excitation is called action potential about 20mv.

* The Action potential exists, the cell is said to be depolarised.

The relationship between the action potential and Muscle contraction



* The intensity of stimulus, which is assumed to be greater than the threshold of stimulus, the action potential is always the same for any given cell. This is known as ALL-or-nothing Law.

* A stimulus voltage generally does not affect a cell while it is changing its polarisation. Following the generation of an action potential, there is a brief period of time during which the cell cannot respond to any new stimulus

* Absolute Refractory period:

It is the time duration of cell non response to further stimuli. It is about 1 milli second in nerve cells. All or nothing law states that regardless of method of excitation of cell (or) by the intensity of stimulus, the action potential is always same for any given cell

* The Absolute refractory Period, there occurs a relatively refractory period during which another action potential can be triggered but a higher stimulus is required to reinitiate an action potential and subsequent contraction of muscle.

* In nerve cells, the relative Refractory Period is several milli seconds.

* The rate at which an action potential moves down a fiber of a nerve cell (or) is propagated from cell to cell is called propagation rate (or) conduction velocity.

* The conduction velocity varies in nerves depending on the type and dia meter of the nerve fiber. and is 20 to 140 m/s. But in heart muscle, it is very slower ranging from 0.2 to 0.4 m/s.

Key points:

1. Resting & Action Potentials of human body
2. Active & passive transport of the cell.
3. Characteristics of Resting potential

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TITLE: Type of Electrodes

OBJECTIVE:

The Students are able to understand about different type of electrodes

APPLICATIONS:

1, Ag – AgCl electrode

UNIVERSITY QUESTIONS:

1. Define Electrode. & its type,
2. Define : Electrode paste
3. Explain details about different type of Electrode

NOTES

Electrodes :

Electrodes are used to pick up the electric signals of the body. The various type of electrodes are given below

- Surface electrode
- Micro electrode
- Depth & Needle electrode
- Chemical Electrode

Half cell potential

* The voltage developed at an electrode-electrolyte interface is termed as half cell Potential

* The Half cell ~~Potential~~ Potential is obtained using the Surface electrode.

Perfectly polarised electrode:

The electrode in which no net transfer of charge occurs across the metal electrolyte interface is called as "Perfectly polarised Electrode"

Perfectly Non polarised Electrode:

The electrodes in which infinite exchange of charge occurs, across the metal electrolyte interface is termed as "Perfectly non-polarised electrodes". Non Polarised electrode will create a variable noise termed as "Artifacts"

Surface Electrode:

- x The surface electrodes are used to measure the potential available from the surface of the skin and are used to sense the potential from heart, brain and nerves.
- x The small area of surface electrodes are used to measure EEG, ENG potentials
- x The Large area of surface Electrodes are used to measure the ECG potentials

Classification Surface Electrodes

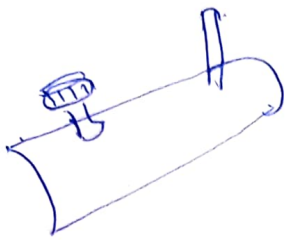
Depends on Area

1) Smaller Area Surface Electrode.
2) Largest Area surface Electrode.

Depends on Constructing

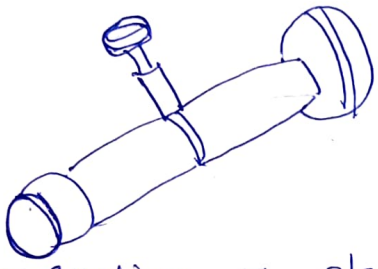
1. Metal Plate Electrode.
2. Suction Cup Electrode
3. Adhesive tape Electrode
4. MultiPoint Electrode
5. Floating Electrode

Metal plate Electrode.



* Rectangular (3.5cm x 5cm) and circular (4.75 diameter) plates from Germanium silver, Nickel (or) Nickel plated steel are used as surface electrodes in the case of ECG measurement.

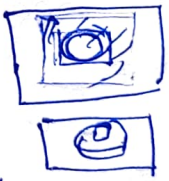
Suction cup Electrode.



* The suction cup electrodes is suited for black surfaces of the body, where the human tissues is very soft.

The Adhesive tabe electrode [The pressure of the surface electrode squeezes the skin may squeeze the electrode paste out] To avoid using this type.

* The Adhesive tape electrode is used to hold the electrodes in the respective place and it retards the evaporation of the electrolyte, present in the electro paste.



Multi point Electrode:-

* It is frequently used for ECG measurement. It contains nearly thousand active contact points. So that, it can be used under any environmental condition.

Floating surface Electrode.

* In floating Electrode, the metal does not contact the body directly, the contact is made to an

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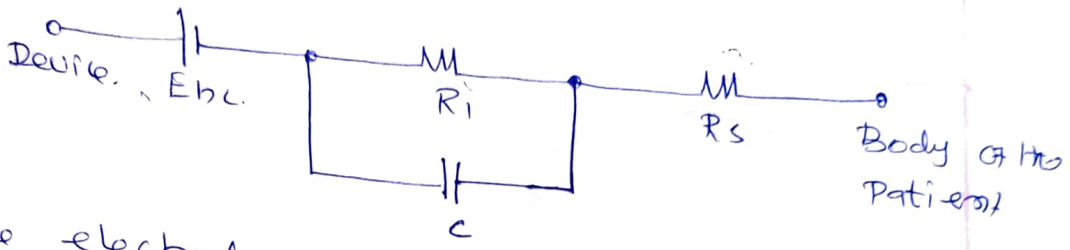
electrolytic bridge., so that Artifact is red

* The floating electrode is other wise known as liquid function electrode

Equivalent circuit of surface Electrode



* The electrode - electrolyte interface will resemble a voltage source having half cell potential (E_{hc}) that is developed due to charge gradient
* In the equivalent circuit, Rs → Skin resistence
  - R_1 → Represents Leakage Resistence
  - C → " Electrode Capacitence
  - E_{hc} → " Half cell potential
* The half cell potential is measured with reference to hydrogen electrode that is placed in the electrolyte near the metallic electrode
* The half cell potential (or) the voltage is expressed by "Nernst equation"

$$E_{hc} = \frac{-RT}{nF} \ln \frac{C1}{C2} \cdot \frac{F1}{F2} = -2.303 \frac{RT}{nF} \log_{10} \frac{C1}{C2} \cdot \frac{F1}{F2}$$

R - Gas const T - Absolute temp in kelvin

n = Valence in Ions, F - Faraday's const.

C1, C2 - Concentration of the selected ion on two sides of the membrane

F1, F2 - Activity coefficient of the ion on the two sides of the membrane.

Key points:

1. The different type of Electrode used to pickup the electrical signals from the human body
2. Equivalent Circuit of surface electrode.

TITLE: Micro Electrodes

OBJECTIVE:

The Students are able to understand the Concept of Micro electrode

APPLICATIONS:

1. ENG

UNIVERSITY QUESTIONS:

1. What are the different types of Micro electrodes
2. write Short notes on: Micro electrode.

NOTES

Micro Electrodes:

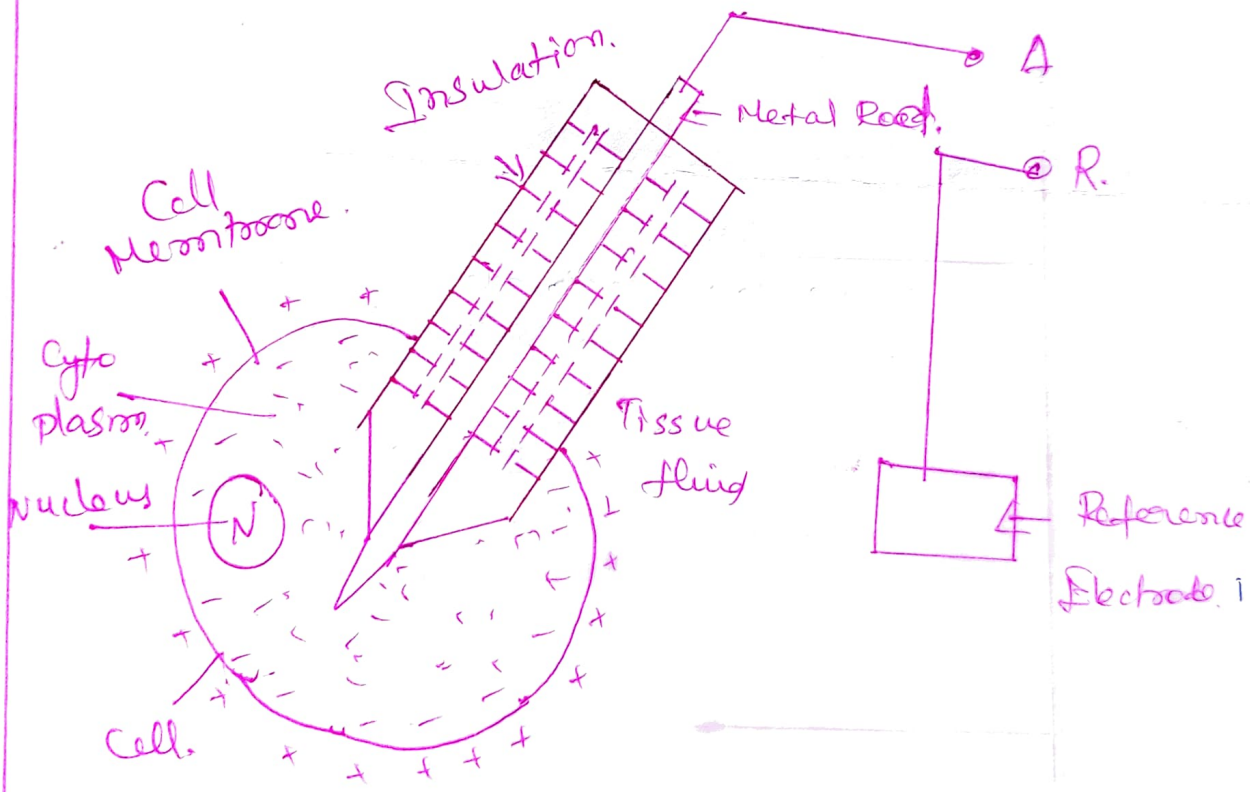
* The Micro Electrodes are normally used to measure the potential with in a single cell.
* Very small in diameter
* Generaly the micro-electrode is located with in the cell, where as reference electrode is placed out side the cell.

classification.

Micro Electrode
- Metallic Electrode
- Non-Metallic Electrode [Micro Pipet]

Metallic Electrode:

* The metal micro-electrodes are formed by electrolytically etching the tip of fine tungsten filament (or) simple stainless steel wire, into a minute structure.
* The Potential within the cell can be measured by using 2 electrodes.
  * Micro electrodes /
  * Reference Electrodes /



fig(a) Metallic Electrode.

* E_A – The metal Electrode – electrolyte potential at the tip of the micro electrode.
  E_R – Reference Electrode – Electrolyte Potential
* The final Potential within the cell is the difference between the micro-electrode potential and reference potential

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The Equivalent circuit for metal Micro electrode is given shown in figure.

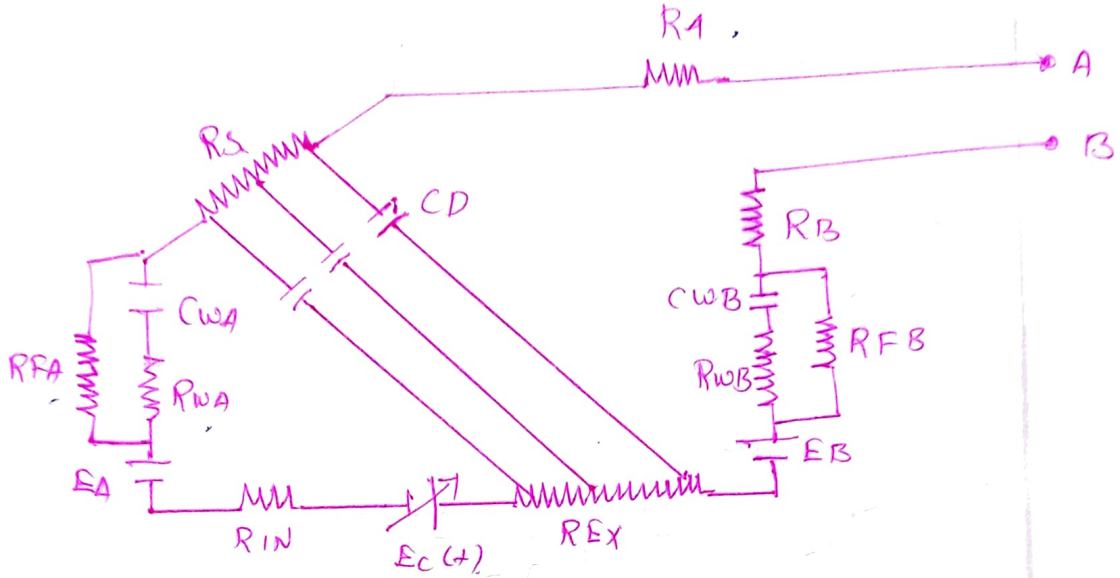
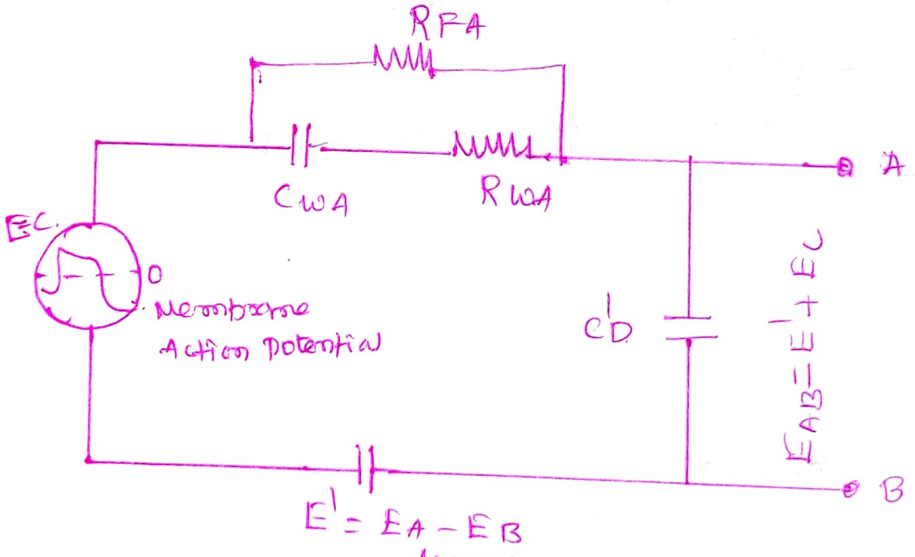


fig (b)



fig(c)

* RA denotes the resistance of the connecting wire which is negligible.
* Rg denotes the resistance of the shaft of the microelectrode, which is also negligible.
* RFA, RWA, & CWA - constitute the impedance of the micro electrode tip - intracellular fluid interface.

Similarly

R_{IW} is the resistance of the Intra cellular fluid

R_B is the resistance of the wire connected to the reference electrode which is negligible.

R_{FB}, R_{WB}, & C_{WB} constitute the impedance of the reference electrode – extra cellular fluid interface.

R_{EX} – Resistance of the Extra cellular fluid.

CD – distributed capacitance between the insulated shaft of the micro electrode & extra cellular fluid.

* the capacitance between the tip of the microelectrode and extra cellular fluid is negligible because the potential difference across it does not change

Fig (c) is the approximate equivalent circuit of fig (b)

* the impedance of the micro electrode tip is inversly proportional to the area of the tip & frequency
* when the electrode output is coupled with an ~~amplifier~~ amplifier, the low frequency components of the bio electric potential will be attenuated if the input impedance of the amplifier is high
* when the input impedance of the amplifier is not high enough, it behaves as a high pass filter

Key Points

* Construction of Metallic electrodes
* Equivalent circuit for Metallic electrode

TITLE: III Micropipet

OBJECTIVE:

The students are able to understand the construction and equivalent circuit of micropipet

APPLICATIONS:

1 EMG (Electromyogram)

UNIVERSITY QUESTIONS:

1. Draw the equivalent circuit of Micropipet
2. explain details about Construction of Micropipet.

Micropipet:

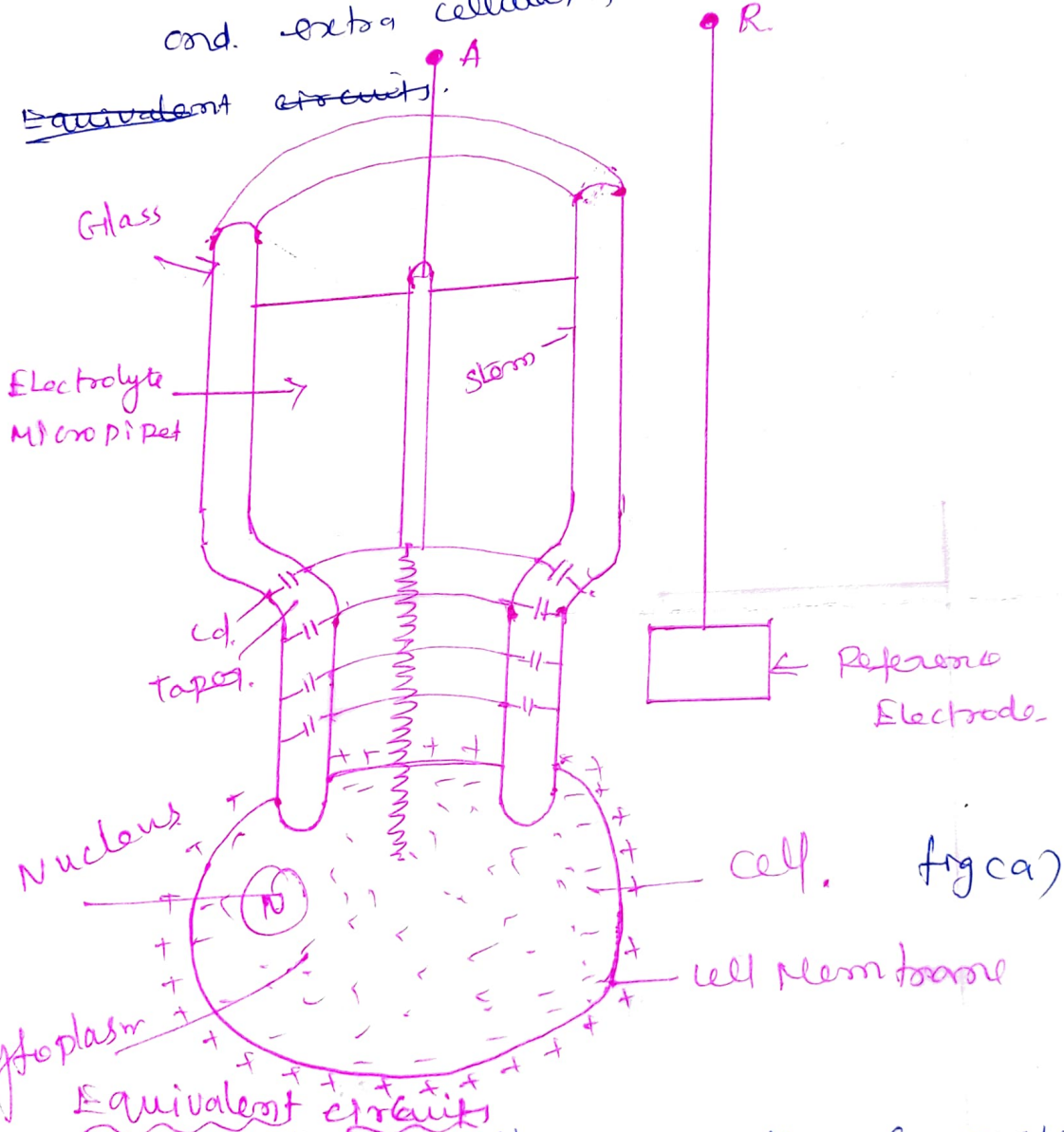
NOTES

* It is also used to measure the Potential within a single cell, but instead of metal electrolyte, non-metallic material is used.
* Generally the simple glass instrument is used.
* The micropipet is filled within an electrolyte, that is compatible with the Cellular fluids

(6)

E_A = The potential between the glass & electrolyte fluid in the micro pipet

E_R = potential between the reference electrode and extra cellular fluid



R_A - denotes the resistence of the connecting wire.

R_{FA}, R_{WA} & C_{WA} - constitute the impedence of the electrode electrolyte interface in the stem of the micropipet

R_T is the resistance of the electrolyte filling the tip of the micropipet which is very large.

R_{IN} & R_{EX} – Resistance of the electrolyte inside the cell & Electrolyte outside the cell.

R_{FB}, R_{WB}, & C_{WB} – constitute reference electrode – electrolyte interface impedance.

R_B – Resistance of the wire connected with reference electrode.

C_D – distributed capacitance existing between the fluid in the pipet & the extracellular fluid

Fig(c) shows approximate version of fig(b)

C_D is the equivalent of distributed capacitance

Fig b

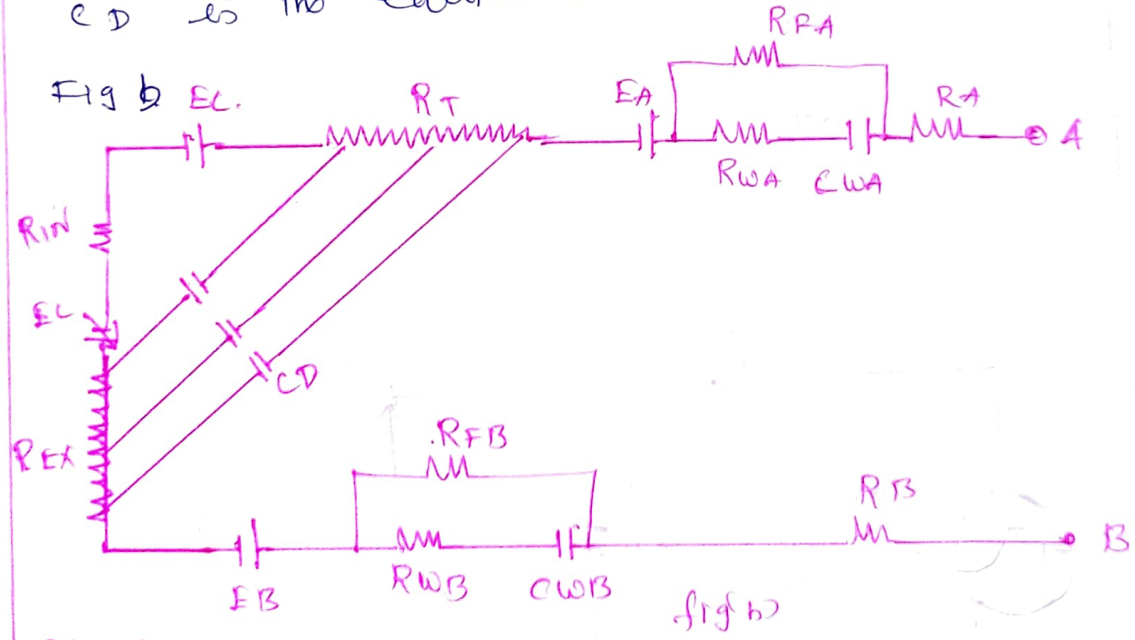


fig b

Fig c)

E_A – Potential between the metal wire and electrolyte filled in the micropipet

E_B – Potential between the reference electrode and extracellular fluid

E_C - Variable cell membrane

E_D - Potential existing at the tip due to different electrolytes present in pipet and cell $E = E_A + E_B + E_D$.

* When the micro pipet is coupled with the amplifier terminals A and B. Then membrane potential E_C is coupled with it via a high series resistance "R_T" and a moderate shunt capacitance 'C_D' along with electrode potentials

* The impedance of the electrodes places a limit on the response time of the circuit such that it behaves as a low pass filter when the input impedance of the amplifier is not high enough.

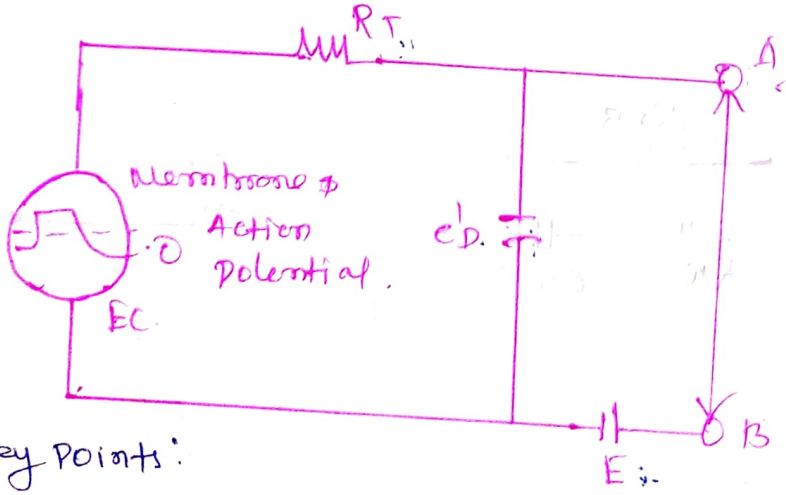


fig (1)

Key Points:

x Construction of Micropipet electrode.

x. Equivalent circuit for Micro pipet electrode

TITLE: Needle Electrode

OBJECTIVE:

The Students are able to understand its construction about needle electrode

APPLICATIONS:

1. ENG

UNIVERSITY QUESTIONS:

1. Draw the equivalent circuit for Needle electrode
2. Write Short Notes on: Needle electrode.

Needle Electrode

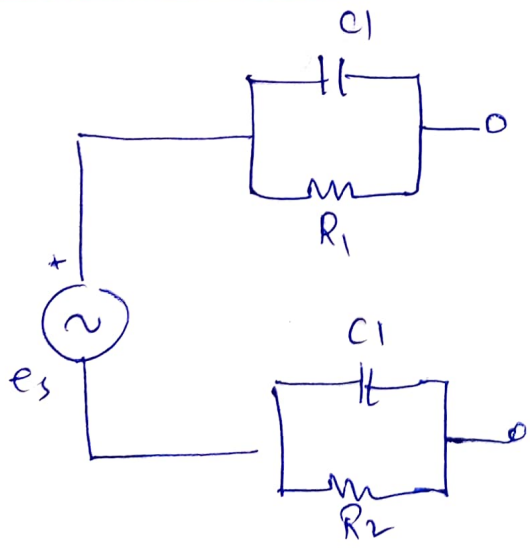
NOTES

* Needle Electrode are used to record the Peripheral nerve's action Potentials (ENG)
* The needle Electrode resembles a medicine dropper or hypodermic needle.
* A Short Length of the fine insulated metal wire is bent at its one end and bent portion is inserted

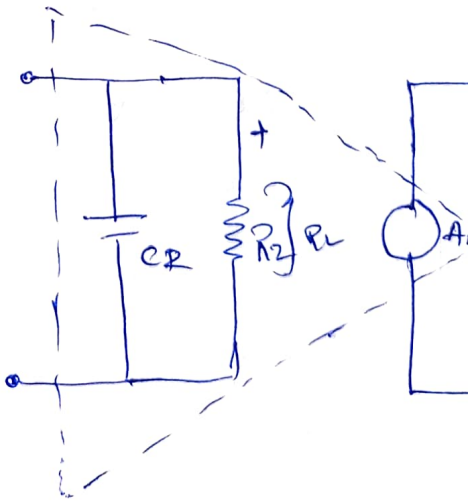
through the lumen of the needle. is advanced into the muscle.

* the needle is withdrawn and t wire is resting inside the muscle.
* when the reference electrode is on the skin, then the needle elect is called monopolar.
* when we insert two insulated into the lumen of the needle, t the two wires consitute bipolar electrode. such that one wire active electrode and other wir reference electrode.

Equivalent circuit



Electrode equivalent circuit



Amplifier

* This type of Electrode used to EMG measurement

* Needle type EMG Electrode are placed directly in a muscle.

* The above shown in figure is simplified equivalent circuit and also the equivalent circuit of the input stage of an amplifier.

* The value of the capacitor C_2 in the Amplifier may be varied to any desired quantity

* Assuming $C_2 = 0$ and the Amplifier gain is A, write down equation showing the output voltage of the amplifier as a function of e_s (signal) and frequency.

$$\left[X_{C_1} = \frac{1}{j\omega C_1} \right]$$

* Determine the value for C_2 that gives electrode amplifier characteristics that are independent of freq. (using C_2 to compensate for C_1)

TITLE: Recording Problem - Measurement with two Electrode.

OBJECTIVE:

The students are able to understand the measurement of biopotentials with two electrode

APPLICATION:

1. ECG, EEG, and EMG.

UNIVERSITY QUESTION:

1. Explain details about measurement of biopotentials with two electrodes.

Biopotential Electrode.

* A wide variety of Electrodes can be used to measure bioelectric events. All can be classified as belonging to one of three basic types.

1. Micro-electrode – Electrodes used to measure Biopotential near or within a single cell.
2. Skin surface electrode - Measure ECG, EEG and EMG potentials from the surface of the skin.

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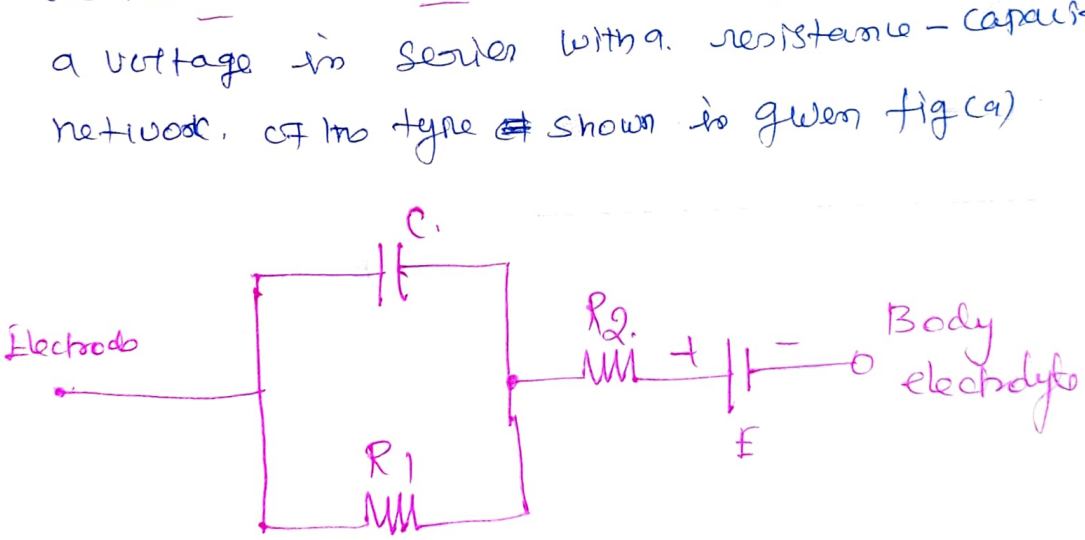
2. Needle electrode: Electrode used to penetrate the skin to record EEG potentials from a local region of the brain or EMG potentials from a specific group of muscles

* All three type of bio potential electrodes have the metal - Electrolyte interface.

* An electrode potential is developed across the interface, proportional to the exchange of ions between the metal and the electrolytes of the body

* The double layer of charge at the interface act as a capacitor

* The equivalent circuit of bio potential electrode in contact with the body consist of a voltage in series with a resistance - capacitance network. of the type shown in given fig (a)



fig(a) Equivalent circuit of Bio potential electrode interface.

* Since measurement of bio electric potentials requires two electrodes, the voltage measured is really the difference between the instantaneous potentials

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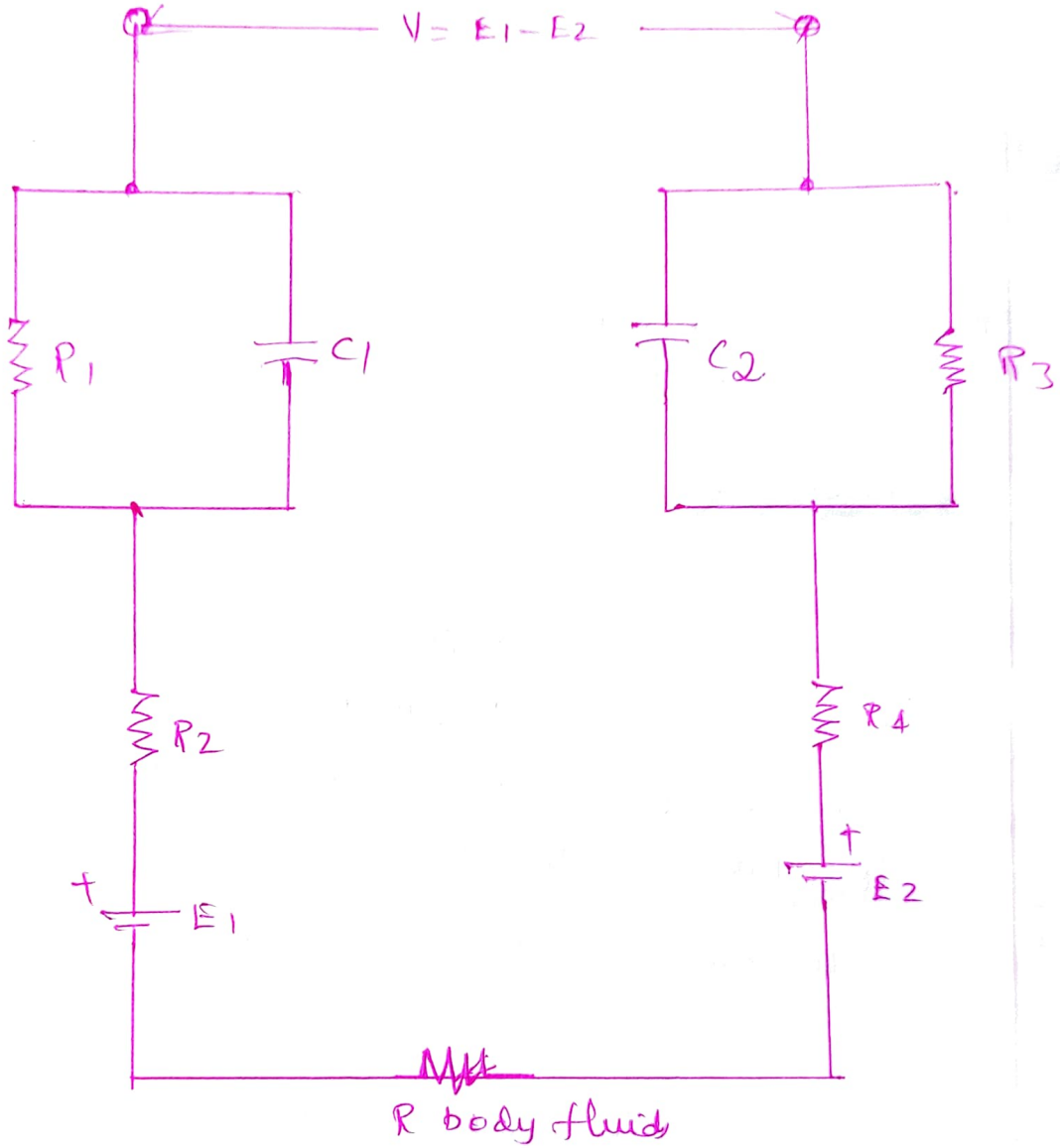
of the two electrodes, as shown in fig (b)



fig(b) Measurement of two potentials with two electrodes - equivalent circuit

* If the two electrodes are of the same type, difference is usually small and depends essentially on the actual difference of ionic potential between the two points of the body from which measurements are being taken.

* If the two electrodes are different, however they may produce a significant dc voltage that can cause current to flow through both electrodes as well as through the input circuit of the amplifier to which they are connected.

+ The dc voltage due to the difference in electrode potential is called the electrode offset voltage.

* Even two electrodes of the same material may produce a small electrode offset voltage.

x Electrode offset voltage, experiments have shown that chemical activity that takes place within an electrode can cause voltage fluctuations to appear without any physiological input.

x. Such variations may appear as noise on a bioelectric signal.

y This noise reduced by proper choice of materials

x Such as coating the electrode by some electrolyte method to improve stability. It has been found that, electrochemically, silver-silver chloride electrode is very stable.

* This type of electrode is prepared by coating a piece of silver with silver chloride.

x The coating is normally done by piece of

silver to bromide. free sodium chloride solution

* The silver ions combine with the chloride ions from the salt to produce neutral silver chloride molecules that coat the silver chloride.

* The resistance – capacitance network are shown above fig (a) and b) represent the impedance of the electrodes as fixed value of resistance and capacitance.

* The impedance is frequency – dependent because of the effect of the capacitance,

* ∴ Both the electrode potential and impedance are varied by an effect called polarization.

* Polarisation is the direct current passing through the metal electrolyte interface.

* Some electrodes are designed to avoid or reduce polarization.

* If the amplifier to which the electrodes are connected has an extremly high input impedence, the effect of polarization or any change in electrode impedence is minimized

* Size & type of electrode are also important determine the electrode impedence.

* Larger electrodes have lower impedance
* Surface electrodes to have impedance 2 to 10 kΩ.
* where needle and micro electrodes much higher impedance
* For the best results, in reading or recording the potentials measured by the electrode, the input impedance of the amplifier must be several times of the electrodes

Key points:

* Problems occurs in measurement of potentials with two electrodes
* Equivalent circuit for in measurement of two electrodes